Field Evaluations and Refinement of New Nitrogen Management Guidelines for Upland Cotton: Plant Mapping, Soil and Plant Tissue Tests (Residual Soil Nitrogen and N Management for Acala Cotton)

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Introduction

Incentives to consider adjusting nitrogen management practices for cotton arise based upon several concerns. High soil and plant tissue N levels can delay harvest, can have negative impacts on efficacy and costs of defoliation, and can increase problems with late-season pests with potential to damage lint quality. Higher than desired N levels during bloom / early boll fill can also promote vegetative development at the expense of fruit retention. A significant additional concern in recent years has been the potential fate of nitrogen applied in excess of crop requirements and resulting potential for groundwater nitrate contamination.

The drive for greater efficiency in fertilization practices in cotton requires improved evaluations of: (a) soil fertility level on a field-by-field basis; (b) a means to evaluate and deal with field-by-field variation in crop growth and nutrient status conditions, some measure of vigor and fruit retention that is adjusted for stage of growth); and (c) an understanding of the required timing for split fertilizer applications in meeting critical plant needs. In this type of system, adjustments in nutrient applications are made depending on levels of residual soil N, irrigation water N, and crop condition, which has been referred to as a “feedback” approach to fertilizer N management. This is in contrast to a “scheduled” approach where fertilizer N is applied more on a routine basis determined by stage of growth or month. The “feedback” approach should have improved potential to reduce losses, improve nutrient use efficiencies, and provide more specific guidelines for use in making N management decisions.

Objectives

A field-based research and demonstration project was initiated to provide further evaluation of the concepts developed in recent University of CA nitrogen management studies in cotton,and to begin evaluation of the potential to integrate rapid laboratory tests for better estimates of mineralizable N. Goals are to demonstrate an integrated N management system based upon soil and plant N status measurements, but incorporating: (1) estimates of crop growth and yield potential; (2) lower initial N applications to reduce potential for leaching losses; and (3) use of split soil N applications and/or foliar applications to supplement supplies when plant sampling indicates good enough yield potential to warrant additional N supply.

Project Description and Approach Used

The 2001 growing season was the first year of this proposed three-year field study. Studies were set up at four locations in 2001 and 2002, but only 3 locations are to be followed to completion in 2002. Sites represent a range of initial soil residual nitrogen levels and soil types, and were located in the central and southern San Joaquin Valley.

Three basic N application treatments were used at each location:

(1) Trt. #1:one-time (early vegetative growth) baseline application of fertilizer N (between 100 and 125 lbs applied N/acre depending upon application equipment, and levels of residual N in upper 2 feet)
(2) Trt #2: one-time treatment receiving a full 150-180 lb N/acre application, with adjustment based upon residual soil nitrate-N in upper 2 feet of the soil profile; and
(3) Trt #3: initial 100 to 125 lbs N/acre application at the timing of first within-season irrigation of the growing season (adjusted to account for residual soil nitrate-N in the upper 2 feet), plus subsequent need for additional N applications (by water run or foliar) assessed based upon measured soil N, yield potential assessed by plant mapping of fruit load, and in consideration of early and mid-bloom petiole nitrate-nitrogen. If data called for a foliar or water run nitrate-N application, it was made between 2 and 3 weeks after first bloom.

In addition, where possible, two additional treatments were added when willing cooperators were found. Several sites had a treatment added in which no supplemental N was added, in order to allow for yield and petiole nitrate-N analyses where only residual soil N supplies could be utilized. At all sites in 2002, another treatment was added in which the initial application rate was between 150 and 180 lbs/acre (adjusted for residual nitrate-N in the upper 2 feet of the soil profile) and petiole and fruit load information was utilized to decide if a supplemental foliar application would be made at 2 to 3 weeks after first bloom. Field sites selected for the experiment differ in soil types and in estimated effective rooting depth, but were selected to represent the difficult management range of “low” to “intermediate” in soil residual N in the upper 2 feet versus 4 feet of profile, where the ability of soil nitrate tests to accurately predict plant-available N carries more risk to potential yields. Pre-season soil samples to a depth of four feet were collected for analysis of residual soil NO_3^--N levels, PO4-P, exchangeable-K, Zn and mineralizable N. Soil NO3-N analyses on air- dry soils collected after planting were performed within a few days of sample collection at a commercial testing laboratory in the San Joaquin Valley. These samples were analyzed to develop estimates of available N used in determining applied N rates for the study. Duplicate samples were sent to the DANR State Testing Laboratory (KCl extract NO3-N, PO4-P , Exchangeable-K, Zn).

Samples were collected at all sites within two weeks after planting to a depth of four feet for initial NO3-N and mineralizable N tests to allow for the comparison of residual N made in the upper 2 feet, upper 3 feet and upper 4 feet of the profile. The reason for this is that two foot sampling depths are commonplace among advisors and agronomists, while recommendations for pre-season or early-season soil sampling to 3 or 4 feet depths would require some convincing evidence that it significantly improves estimates. In addition, in both the spring (early post-plant) and again near harvest in the fall, soil samples were collected to a depth of 8 feet in one-foot increments and analyzed for soil NO_3-N, Cl-, exchangeable K and PO_4-P. The soil NO_3-N and Cl- data will be used in combination with irrigation water NO_3-N and Cl- to estimate leaching loss potential at any sites where irrigation water Cl- levels are high enough to allow these calculations. Irrigation water samples were taken and analyzed for NO_3-N, and the timing and amounts of applied water estimated to allow calculation of irrigation water contributions to applied N.

Soil Mineralizable Nitrogen Evaluations One of the primary problems with soil N tests is the general uncertainty many agronomists, soil scientists and consultants express in assessing the accuracy and adequacy of soil nitrate tests to explain the likely dynamics of plant-available N. Since NO3-N is just part of the soil N pool, and ammonium-N tests are highly variable and of limited value in many of our western soils, there remains interest in other tests that might be better-correlated with plant-available N. Two methods are being compared as part of this experiment, strictly for comparison with the amounts of residual nitrate-N determined with our current sampling methods. Gianello and Bremner (1982) developed a "hot KCl" method to assess potentially available organic N in the soil. The procedure involves air-dried soil samples that are heated with 2N KCl to 100C for a 4-hour period, followed by cooling and determination of ammonium-N. An alternative method developed by Franzluebbers et al (1996) yields potential N mineralization based upon a 24-hour incubation, in which soil samples are placed in airtight tubes, water is added and a 24-hour incubation is done at 25 C. After this period, the amount of CO2 evolved is determined by titration.

Results and Conclusions
FIRST YEAR – Field Nitrogen Management Studies

In the four field test sites, residual soil nitrate-N analyses done on soil samples collected within 3 to 6 weeks following planting yielded the following average quantities in the surface two, three and four foot depths of the soil profile.

Table 1. Site average soil nitrate-N in upper 60, 90 or 120 inches of soil at planting as function of location.

Depth of soil sampled (inches)	***2001 Field Study Sites*** Average Soil Nitrate-N (lbs N/acre as NO3-N on soil dry wt basis)							
	Site A (Kern)		Site B (Shafter)		Site C (Fresno)		Site D (WSREC)	
	Avg. [1]	S.E.	Avg.	S.E.	Avg.	S.E.	Avg.	S.E.
0-60	69	7	41	3	113	17	58	9
0-90	84	14	61	8	128	22	72	11
0-120	116	17	86	7	176	23	97	10

[1] Avg. = average; S.E. = standard error across samples

Based upon our prior five-year study, recommendations for nitrogen fertilization for this study (based upon spring soil nitrate data in the upper two feet of the soil profile) would be:

- if less than 55 lbs N as NO3-N/acre, then fertilizer application recommended at 125-175 lbs N/acre unless low yields predicted due to late planting or field history
- if between 55 and 100 lbs N as NO3-N/acre, then reduce fertilizer application recommendation to 100 to 125 lbs N/acre, use plant mapping and petiole nitrate analyses to assess yield, plant N status
- if over 100 lbs N as NO3-N/acre in the upper two feet of soil profile, lower fertilizer recommendation to 75 lbs N/acre or less, use plant mapping and petiole nitrate analyses

The data shown above indicates the dilemma in use of soil test data for the upper two feet of soil profile. If a crop (such as cotton) is expected to have roots active in water and nutrient uptake below two feet, there is an advantage in collecting deeper soil samples in order to attempt to account for deeper, potentially available N. An additional advantage to early post-plant information on deeper (to three or four feet) soil nitrate-N would be that it provides some incentive to avoid application of large amounts of early-season irrigation that could leach soil nutrients. Based upon these results, it would significantly improve nutrient management information to collect soil samples to a depth of three or four feet, instead of only two feet. It is important to note, however, that since soil nitrate losses can occur and since there are other potential sources of N represented in the soil N pool, identification of potential soil nitrate-N reserves will still not fully represent plant-available N for making fertilization decisions. This is where estimates of crop yield potential (from plant mapping) and plant nutrient status (from petiole nitrate analyses) can play an important role. Ranges of petiole nitrate-N from 2001 field sites for specific dates were as shown in Table 2.

Table 2. Petiole nitrate-N as a function of growth stage in 2001 sites for treatment 3 (late supplemental N)

Date of petiole sampling (by growth stage)	***2001 Field Study Sites*** Petiole Nitrate-N (mg/kg x1000 as NO3-N on dry wt basis) * data from treatment # 3 only (low initial N / supplemental N treatment)							
	Site A (Kern)		Site B (Shafter)		Site C (Fresno C)		Site D (WSREC)	
	mg/kg x 1000		Mg/kg x 1000		Mg/kg x 1000		Mg/kg x 1000	
	Low [1]	High	Low	High	Low	High	Low	High
Early bloom (first bloom +/- 5 days)	14.7	18.9	13.3	15.2	13.0	18.4	12.2	14.1
15-20 days after first bloom	7.7	12.9	9.1	11.5	7.3	11.6	7.7	10.5
28 to 35 days after first bloom	6.3	8.8	4.5	6.9	5.7	9.3	6.0	7.4

[1] Data shown shows the range of values for averages within reps of the treatment; low = low average; high = high rep average

Plant mapping data was used to help interpret the petiole data for use in recommendations for supplemental nitrogen. Yield potential estimates at the different sites based upon within-season plant mapping data indicated relative yield potentials and timing of the crop as: (a) Kern - moderate yield potential / early and mid-season fruit set most important; (b) Shafter - low yield potential / early and mid-season fruit set most important; (c) Kings - moderate to high yield potential / well-balanced fruit set; and (d) Fresno - moderate to high yield potential / well-balanced fruit set. The petiole data and yield potential estimates were used to assess the need for a supplemental fertilizer application, resulting in a late side-dress fertilizer application on the Kern, Kings and West Side REC location in treatment #3.

Yield responses to the applied N treatments in 2001 indicated significantly higher yields with all N application treatments when compared with no supplemental N in three of the four locations, indicating that despite the initial residual N levels shown in Table 1 in the upper 2, 3 or 4 feet, additional N fertilizer was needed to achieve moderately high yields (Table 3). At the Fresno County site, high initial residual nitrate-N across all treatments resulted in no difference in yield between no N and moderate applied N treatments (Trts. 1, 3), but resulted in a yield decrease due to excessive vegetative growth in the high N application treatment (Trt. 2). At all four sites in 2001, use of the feedback management approach (Trt. 3) resulted in a 3 to 5% apparent yield improvement over the high N treatment , but this was significant only at two sites, the low residual nitrate-N site at the West Side REC and the high residual N site in Fresno County (Table 3). Use of the feedback approach (trt. 3) only improved yields over the low N application treatment (Trt. 1) at one site (low residual N site at West Side REC). Impacts on soil nitrate-N accumulation patterns at depths from 4 to 8 feet deep in the soil profile have not yet been analyzed, but samples were collected to provide these details on potential downward movement or leaching loss potential.

Table 3. Lint yield and gin turnout percentage data as a function of site and treatment in 2001.

Site / location	***2001 Field Study Sites***							
	Lint Yield (lbs lint per acre)				Gin Turnout (percent)			
	Trt 1	Trt 2	Trt 3	No N	Trt 1	Trt 2	Trt 3	No N
Kern Co.	1517a	1542a	1615a	984b	33.2	33.1	32.8	34.9
Shafter	1291a	1292a	1227a	678b*	36.3	36.4	36.2	38.4
Fresno Co.	1689 a	1435b	1734a	1665a	34.6	34.1	34.5	34.3
West Side REC	1807b	1815ab	1896a	1331c	36.5	36.3	36.2	37.6

* only 2 replications available'
** yields followed by a different letter were significantly different at 5% level by LSD method.

Mineralizable Nitrogen Analyses
Preliminary analysis of the results has shown positive correlations and fairly good agreement (r2 = 0.79) between mineralizable N estimates using the hot KCl and incubation methods. In analyses of 2001 samples completed to date for the upper two feet of the soil profile, mineralizable N estimates average 142 percent of soil nitrate-N values in post-planting analyses, but only 107 percent of soil nitrate-N values in samples collected after harvest but before fall tillage operations. It must be acknowledged that these 2001 analyses have been on low organic matter soils with sandy loam and clay loam textures and where land application of dairy waste or large amounts of crop residue were not part of the management. Other soil types are represented in some of the other soil samples as yet unanalyzed in this project, and one site in 2002 had significant crop residue and organic N returned prior to the 2002 cotton planting. Some results and comparisons should be available to be summarized by later in 2002. The next phase in the mineralizable N analyses will be evaluation of soil samples from 2002 project sites, and this will commence in fall, 2002.